

3.0 SERVICE HISTORY

The team examined the service history of known instances of fuel tank explosions resulting from internal or external ignition sources in the transport airplane fleet (including turbofan and turboprop airplanes) over the last 40 years.

3.1 METHODOLOGY

Appendix H, Safety Analysis Task Team Final Report, contains a detailed description of each event and the findings of the investigating authority. A description of the mitigating actions taken subsequent to the event to minimize its recurrence is also included in the appendix.

Appendix H summarizes 16 fuel tank explosion events, which are divided into *operational events* (i.e., those occurring on an airplane where passenger-carrying flight was intended) and *refueling and ground maintenance events*. They were grouped by cause (lightning, engine separation, refueling, maintenance, etc.) and then categorized by operational phase, ignition source, type of fuel tank involved, and fuel type.

The team established ground rules to guide this evaluation. First, the team determined that a forecast of future events should be based on the residual risk of recurrence of past events. In addition, the benefits forecast should be based on events that inerting would prevent effectively. As such, the team decided that accidents resulting from external ignition sources that breached the fuel tank would not be used to forecast future events. This ground rule is consistent with that used by the team that developed DOT/FAA/AR-99/73, *A Benefit Analysis for Nitrogen Inerting of Aircraft Fuel Tanks Against Ground Fire Explosion*. The Safety Analysis Task Team notes that inerting may offer some benefit in preventing fuel tank explosions caused by small explosive devices that would not otherwise result in a catastrophe. However, those benefits could not be quantified because of uncertainties related to secondary ignition sources and the loss of nitrogen following breach of the fuel tank.

In addition, the effectiveness of the actions taken subsequent to the event to minimize its recurrence were assessed based on

- Identification of the ignition source.
- Confidence level that mitigating action addressed the ignition source.
- Implementation level of the mitigating action or actions.

Once these data and ground rules were in place, a trend and residual risk analysis was conducted.

3.2 ANALYSIS

The starting point of this analysis was the table of events in the 1998 ARAC FTHWG final report. The events contained in that report were based on the *FAA Notice of Fuel Tank Ignition Prevention Measures* published in the *Federal Register* on April 3, 1997. The data sources used were accident and incident reports provided by investigating organizations, regulatory authorities, and original equipment manufacturers' (OEM) safety-related databases. The level of details reported in the early events was sometimes limited, depending on the event location in the world and the type of event (i.e., whether it involved an internal or external ignition source).

Late in the study period for this ARAC, a fuel tank explosion occurred in Bangkok, Thailand. While it is understood that the accident investigation is ongoing, the NTSB has released information indicating that the wreckage shows evidence that the CWT exploded and that the ignition source for that fuel tank has yet to

be determined. This team has not been involved in that investigation and does not wish to publish findings in advance of the investigating authority. However, the event appears to fit the guidelines set forth by the FAA Tasking Statement, and the team decided to include it as a statistical data point on which to base the forecast of future accidents.

3.2.1 Analysis of Previous Tank Explosions

The data indicates a difference in the safety levels of wing tanks and CWTs. The former are force-cooled by air flowing over the wings, whereas the latter, being located in the fuselage between the wings, are cooled less efficiently. Other auxiliary tanks are also housed within the fuselage. Unlike wing tanks, fuselage tanks may be located adjacent to heat sources.

There have been no known internal ignition sources that resulted in a wing tank explosion in 900 million hours of operation by the commercial transport fleet. All wing tank events have been the result of known external ignition sources (e.g., lightning strike, over-wing fire, refueling, or maintenance error). Corrective actions to prevent recurrence of externally initiated wing tank events have been in place for many years and have been demonstrated to be effective. It has also been observed that the use of less volatile fuel (e.g., Jet A versus JP-4) enhances safety.

Over the years, CWTs have accumulated considerably fewer operating hours than wing tanks (e.g., a Boeing 737 has two wing tanks and one center tank, so it accumulates wing tank hours at twice the rate of CWT hours). Because the equipment in wing and center tanks is similar (i.e., equivalent in types and numbers of potential ignition sources), there should be significantly fewer CWT events than wing tank events. In actuality, however, the number of events is approximately equal for two reasons. First, flammable vapors are present in center tanks a greater percentage of the time because they are not as well cooled. Second, potential internal ignition sources in the wing tanks are more often submerged—and thus present less risk—than they are in CWTs, which are not filled unless additional range is required.

With the exception of the three most recent CWT events and the 1989 Bogotá event, the causes of all other CWT events have been addressed by actions designed to prevent or minimize their recurrence. The 1989 Bogotá accident, which involved a breach of the fuel tank because of a high-explosive charge, violated one of the ground rules this team established as the basis for forecasting future events.

For the three most recent CWT events, the exact ignition sources have not been identified. While corrective actions to identify and minimize potential ignition sources are now being put in place, a means to reduce flammability in heated CWTs should be pursued.

The team concluded that the 1990 Manila, 1996 New York, and 2001 Bangkok events should form the basis for forecasting future events.

3.2.2 Postcrash Fuel Tank Fires

As suggested by the Tasking Statement, the Safety Analysis Task Team evaluated the data provided by DOT/FAA/AR-99/73. The Safety Analysis Task Team accepted the findings of this report and chose not to duplicate effort in this area. The report considered 13 survivable accidents worldwide in which a fuel tank explosion occurred but was not the prime cause of the accident. Each of the accidents was analyzed in depth to assess the number of lives that might be saved if nitrogen inerting systems were used. The predicted number of lives saved per year from this analysis were reported as

- Ground nitrogen inerting, center tank only: 0.3
- Ground nitrogen inerting, all fuel tanks: 2.4
- Onboard nitrogen inerting, all fuel tanks: 6.0

The team used this data to determine the forecast number of lives saved over the study period. Based on assumed annual fleet growth rates and the implementation assumptions (discussed in the estimating and forecasting section), the team forecasts that GBI of the CWT would save 5 lives worldwide over the 16-year study period. Similarly, onboard inerting of all fuel tanks would save 101 lives worldwide over the 16-year study period.

The report concludes

The predicted potential number of lives saved per year is relatively small compared to other survivability factors. One of the reasons that nitrogen inerting may not be effective, in terms of saving lives in the 13 accidents analyzed, is that in many cases fuel tanks were ruptured when the airplane impacted the ground. Any nitrogen in the fuel tanks is likely to have escaped with the spilled fuel. The system is only effective when the fuel tanks are not significantly ruptured.

3.3 CONCLUSIONS

The following conclusions from the service history review can be drawn:

- There is a close relationship between the incidence of explosions in wing tanks and the use of “widecut fuel” (e.g., JP-4).
- Wing tanks operating with less volatile Jet A type fuel have demonstrated an acceptable safety record.
- In comparison, heated CWTs are more vulnerable to explosion in the presence of ignition sources.
- The three most recent events (1990 Manila, 1996 New York, 2001 Bangkok) form the basis for forecasting future events.
- Inerting fuel tanks may enhance occupant survival in accidents in which a fuel tank explosion occurs but is not the prime cause of the accident.

